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Project Summary

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Microwaves, Hyperthermia, and Human Leukocyte Function

Norbert J. Roberts, Jr., Shin-Tsu Lu, and Sol M. Michaelson

The objective of this study is to determine whether exposure to microwaves (2450 MHz) affects the function of human leukocytes in the resting state and during antigenic or mitogenic challenge. This publication is a summary report of the construction and calibration of a waveguide exposure system for the exposure of human mononuclear leukocytes to 2450 MHz (CW) microwave energy. A description of the dual vial waveguide exposure facility for *in vitro* irradiation of human leukocytes is presented. Calorimetric determinations of specific absorption rates (SAR) were made using heating curves measured with a microwave transparent Vitek 101 Electrothermia Monitor. The correlation between SAR and forward power was highly significant (r = 0.95). At a forward power of 0.55 W, the averaged SAR was approximately 33 mW/ml. However, inhomogeneity and significant resonance absorption were noted in the dual vial waveguide exposure facility. A 30-point measurement of SAR distribution revealed that the SAR at any of the measured points could range between 0.12- and 3.94-fold of the average SAR within the given vial. Measurements indicated that this variability in SAR values did not create significant thermal gradients within the vials when external agitation was applied.

This Project Summary was developed by EPA's Health Effects Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Microwave radiation has many current uses that result in public exposure, with very little information available on the effects of microwaves on man. Investigators have reported increased spontaneous transformation of lymphocytes from animals that have been exposed to microwaves. These effects are still of unknown functional significance. Quantitation of thermal variables is difficult but it is critical to understanding these effects. This study will determine whether microwave exposure of human mononuclear leukocytes *in vitro* will similarly affect these cells, and will determine whether such effects are beneficial or detrimental and finally, will determine the influence of thermal flux in these reactions. In addition, the studies will explore the effects of microwave-induced hyperthermia on the function of human leukocytes in host defenses that are pertinent when challenged by bacteria, viruses, toxic foreign material and neoplastic tissue.

Human mononuclear leukocytes will be exposed *in vitro* to microwaves in a 37°C environment to effect no change in temperature and to attain temperatures in the range of 37 to 42°C, to provide a definition of temperature-response relationship. Low equivalent

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power densities (<0.5-10 mW/ml) will be specifically examined. Exposure without temperature increase will be studied initially. The function of these cells, measured by transformation response to mitogen or antigen, will be assayed and compared to that of cells treated concurrently in a like fashion with the exception of microwave exposure. The latter cells, in studies of temperatures >37°C, would have their temperature set by exposure to appropriate ambient temperature conditions.

This report details the construction and calibration of the dual vial waveguide system to be used for the *in vitro* exposure of human leukocytes at 2450 MHz.

Technical Discussion

The study reached these objectives: (1) design, acquisition and construction of the microwave dual vial exposure system; and (2) dosimetry analysis of the system. Analysis of dosimetric and thermal characteristics constituted the major scientific effort after system procurement and construction.

Figure 1 shows the block diagram of the waveguide exposure facility for cell exposure to microwaves. The waveguide exposure chamber dimensions are shown in Figure 2.

Calorimetric determination of specific absorption rate (SAR) was made using a microwave transparent Vitek 101 Electrothermia Monitor. SAR values were determined using heating curves at steady state [$Ln(\Delta Tss-\Delta T) = Ln\Delta Tss-k\cdot t$]. Heating analysis was employed for the following reasons: (1) deviation from linearity occurs consistently earlier in the cooling curve than in the heating curve; and (2) a slower and larger deviation is noted in the cooling constant determined by cooling analysis than by heating analysis. Table 1 shows the calorimetric determination of SAR using heating analysis. Specific absorption rates were also determined from the power reading sampled by the bidirectional coupler. SAR determinations of the dual tube waveguide exposure facility are shown in Table 2.

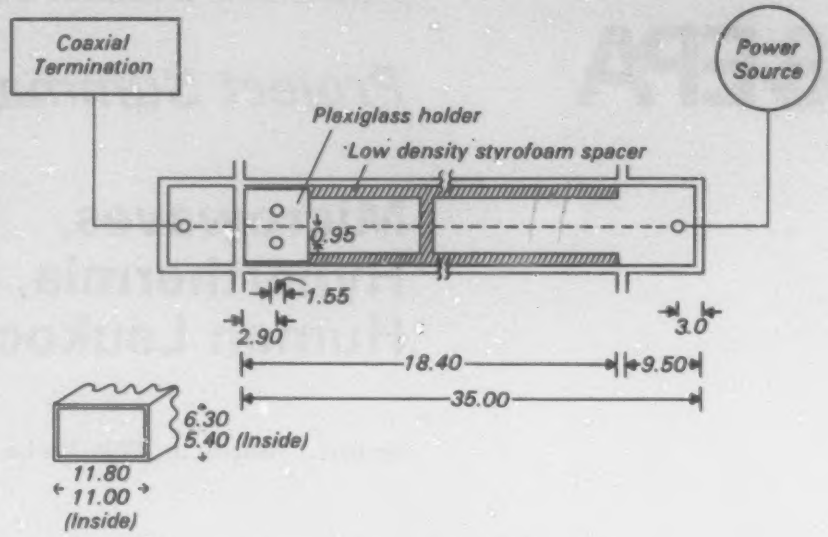

Figure 2. Dual vial waveguide exposure chamber.

Determination of SAR under different dosimetric procedures is shown in Table 3. SAR determinations using muscle phantom material in the vials and medium in the vials with agitation but no insulation and under non-steady-state conditions gave the highest SAR values. A 30-point measurement of SAR distribution in the vials using muscle phantom material showed 0.12 to 3.94-fold variation from the averaged SAR for the vial.

Conclusions

Inhomogeneity and significant resonance absorption were noted in the dual vial waveguide exposure facility. A 30-point measurement of SAR distribution revealed that the SAR at any of the measured points could range between 0.12- and 3.94-fold of the average SAR within the given vial. However, such variable SARs did not create significant thermal gradients within vials when external agitation was applied. The differences in averaged SAR between vials of the present dual-vial waveguide system were not significant, irrespective of the method of quantitation used. This, as well as the fact that much lower averaged SAR values are planned for

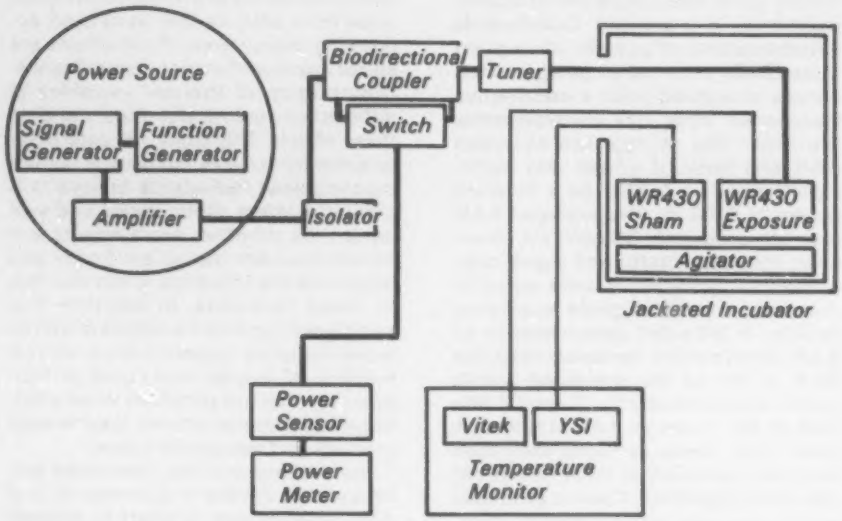

Figure 1. Microwave exposure system

Table 1. *Calorimetric Determination of SAR Using Heating Analysis*

Forward Power[a] (W)	ΔTss (°C)[a]	k (min^{-1})[b]	SAR (mW/ml)[c]
0.22	2.28	-0.0617	9.54
0.33	3.04	-0.0928	15.96
0.45	3.47	-0.0710	16.70
0.55	4.91	-0.0794	26.49
0.55	4.53	-0.0961	29.57
0.67	4.79	-0.0751	24.45
0.67	4.57	-0.0921	28.59
0.77	6.98	-0.0763	35.68
0.78	6.44	-0.0856	37.89
0.78	5.63	-0.0824	31.48
0.79	5.10	-0.0864	29.92
0.89	7.24	-0.0798	39.22
0.89	6.40	-0.0841	36.54
1.00	6.60	-0.0783	35.12
1.01	7.03	-0.0882	42.10
1.01	7.43	-0.0942	47.54
1.10	6.40	-0.0902	39.20
1.13	8.10	-0.0896	49.26
1.18	9.24	-0.0809	50.78
1.28	9.39	-0.0909	57.95
		-0.0838	
		±0.0087 (mean ± S.D.)	

[a] ΔTss = steady state temperature increment.
[b] k = cooling constant.
[c] SAR: specific absorption rate.

Table 2. *Comparison of SAR's for Right and Left Vials*

Forward Power (mW -20.4 dB)	SAR, Left Vial	SAR, Right Vial
0.1	0.93	0.93
0.5	4.70	4.69
0.8	7.51	7.50
1.0	9.40	9.38
1.5	14.09	14.08
1.8	16.92	16.88
2.0	18.80	18.78
2.5	23.51	23.46
2.8	—	26.30
2.85	26.80	—
3.0	28.21	28.17
3.5	32.91	32.89
3.8	35.74	35.71
4.0	37.61	37.60
5.0	—	47.03
5.1	47.97	—
6.0	—	65.43
6.1	57.38	—
7.0	65.84	—
7.2	—	67.73
8.3	—	78.07
8.4	78.98	—
9.2	86.48	86.54
10.0	93.98	94.06

the biological work, indicates that this exposure system can provide an assessment of the importance of inhomogeneous SAR in the absence of substantial compromise by thermal mechanisms.

Recommendations

The construction and dosimetry measurement phase of this project has gone well. The dosimetry should go a long way in evaluating the data of human leukocytes exposed to microwaves. It is recommended that this project proceed to the evaluation of the effects of microwaves on human leukocytes exposed at 2450 MHz in this exposure system.

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Table 3. *Determinations of SAR with Different Dosimetric Procedures*

Procedure	Right Vial	Left Vial
Muscle phantom,[a] Lim d/dt (ΔT) $t \rightarrow 0$	58.7 ± 46.2 (30)[b] 63.4 ± 45.4 (29)	76.1 ± 63.9 (30)[b]
Culture medium, agitated, non-insulated, non-steady-state	80.0 ± 23.1 (4)	72.9 ± 9.2 (4)
Culture medium, agitated, insulated, linear heating rate	34.1 ± 2.9 (4)	31.3 ± 3.2 (4)
Culture medium, agitated, non-insulated, steady-state	26.4 ± 4.4 (4)	28.8 ± 0.7 (4)

[a] Multiple points measured within the vial.
[b] Mean ± S.D. (no. of determinations).

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***Ralph J. Smialowicz** is the EPA Project Officer (see below).*
The complete report, entitled "Microwaves, Hyperthermia, and Human Leukocyte Function," (Order No. PB 81-208 951; Cost: $6.50, subject to change) will be available only from:
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